

Electrochemical Assisted Phosphorus Precipitation of the Liquid Fraction of Dairy Manure in Microbial Electrolysis Cells: A Look into Phosphorus Removal



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Abstract

A cost and energy efficient method of liquid dairy manure solution treatment was investigated with the use of Microbial Electrolysis Chamber technology. The electrolysis chamber would precipitate phosphorus out of solution with the use of an applied voltage and the present microbes in the manure. It was seen that higher voltages around 1.0 V would remove roughly 35% of the total phosphorus out of solution. Reactors with a smaller induced voltage did not follow a steady trend and instead all remove between 8-16% of the total phosphorus in solution. This MEC treatment method does not remove as much as MFC and other removal technologies, but has proven to be very cost efficient. The economic feasibility of this experiment will allow it to be studied more in-depth and on a larger scale.

Background

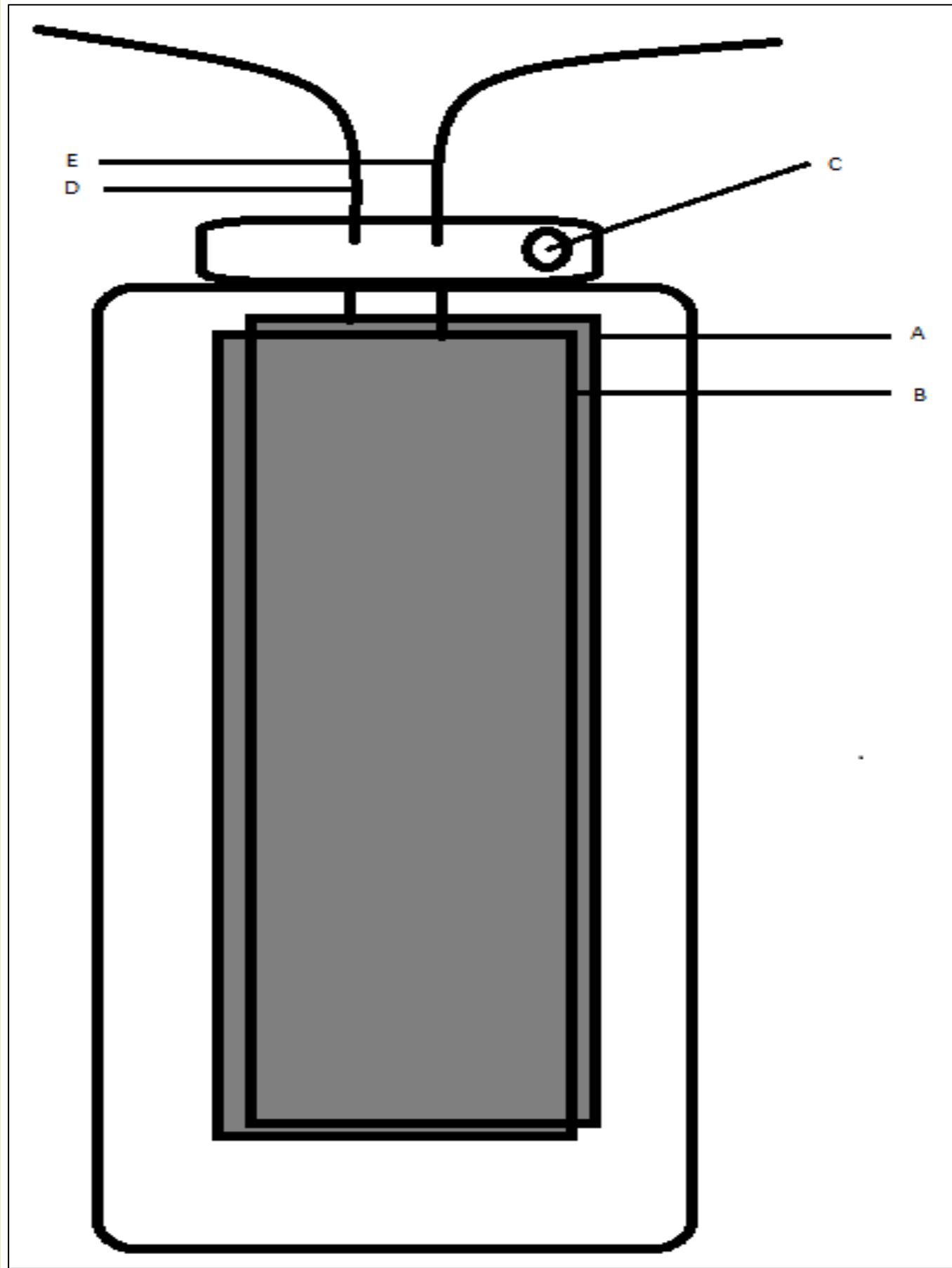
A noticeable elemental transport phenomenon has been increasing as phosphorus from dairy manure escapes agricultural plots into aquatic environments. This phosphorus movement has resulted in increased eutrophication of aquatic autotrophs and consequently results in a detrimental impact to local biodiversity. Through the implementation of microbial- and electrochemically-induced phosphorus precipitation, scientists are working to increase the amount of phosphorus removed whilst conserving energy and decreasing costs of experimentation. A viable technology that is still on the rise is a Microbial Electrolysis Chamber (MEC) which uses an applied voltage symbiotically with microbes to remove the unwanted phosphorus from solution. This technology is not yet perfected, but has shown to be valuable. This experiment is designed to better understand the process and to continue towards an effective solution for phosphorus removal from wastewater and liquid manure solutions.

Experimental Operation

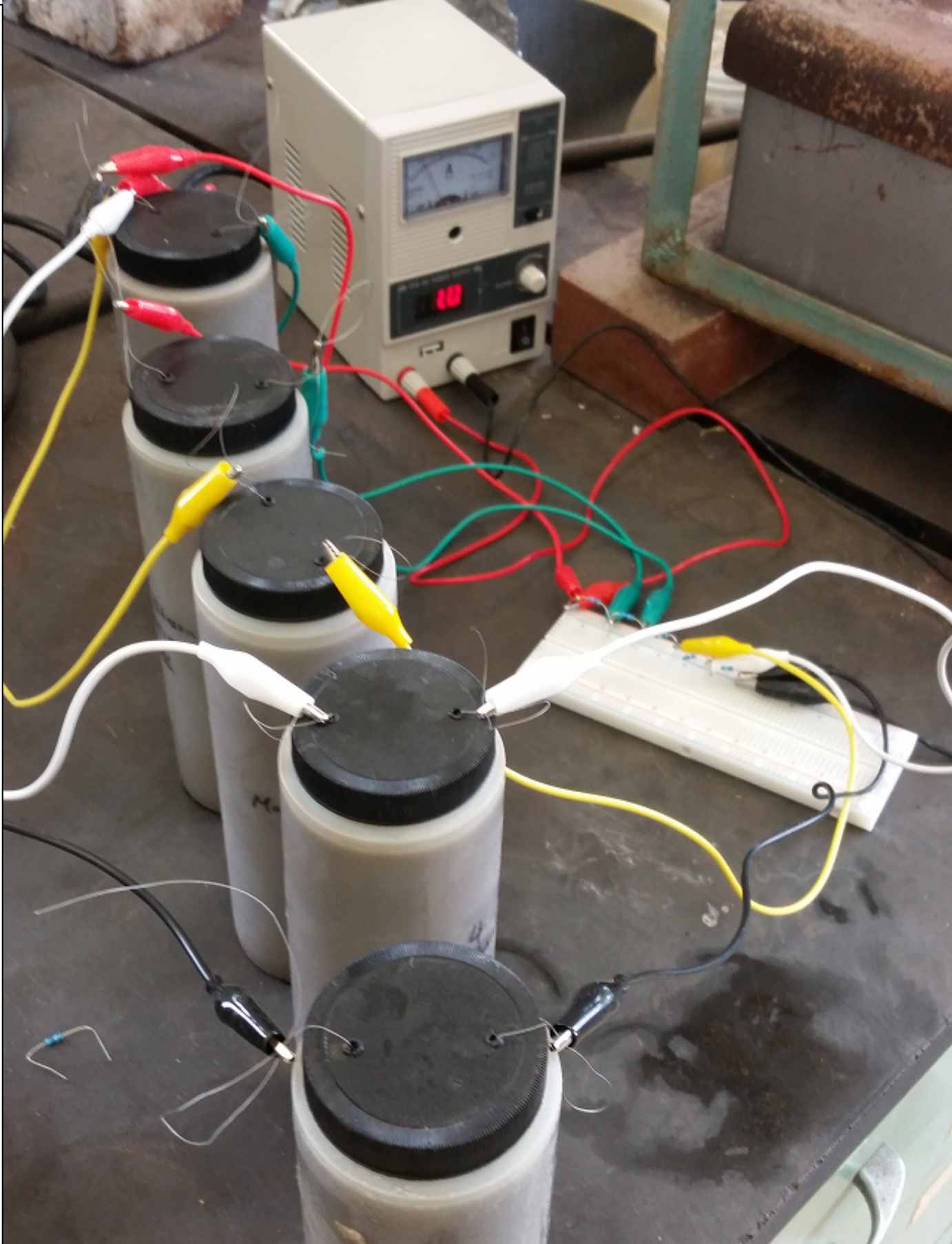
The reactor circuit was set to run for 35 days, continuously, with sample extraction occurring every 1 to 3 days. Voltages on each reactor differs in increments of 0.2 V from 0 to 1.0 V. Sample extraction allowed for a monitoring system on the phosphorus concentration at given times along with trends of phosphorus removal using a Hach® 843 or 845 Phosphorus testing kit.

A fractionation procedure is performed to indicate the amounts of different phosphorus containing compounds in the manure, for classification purposes.

Experimental Set-up



Reactor Configuration. A) Cathode.
B) Anode. C) Extraction position.
D) Cathode wire. E) Anode wire.



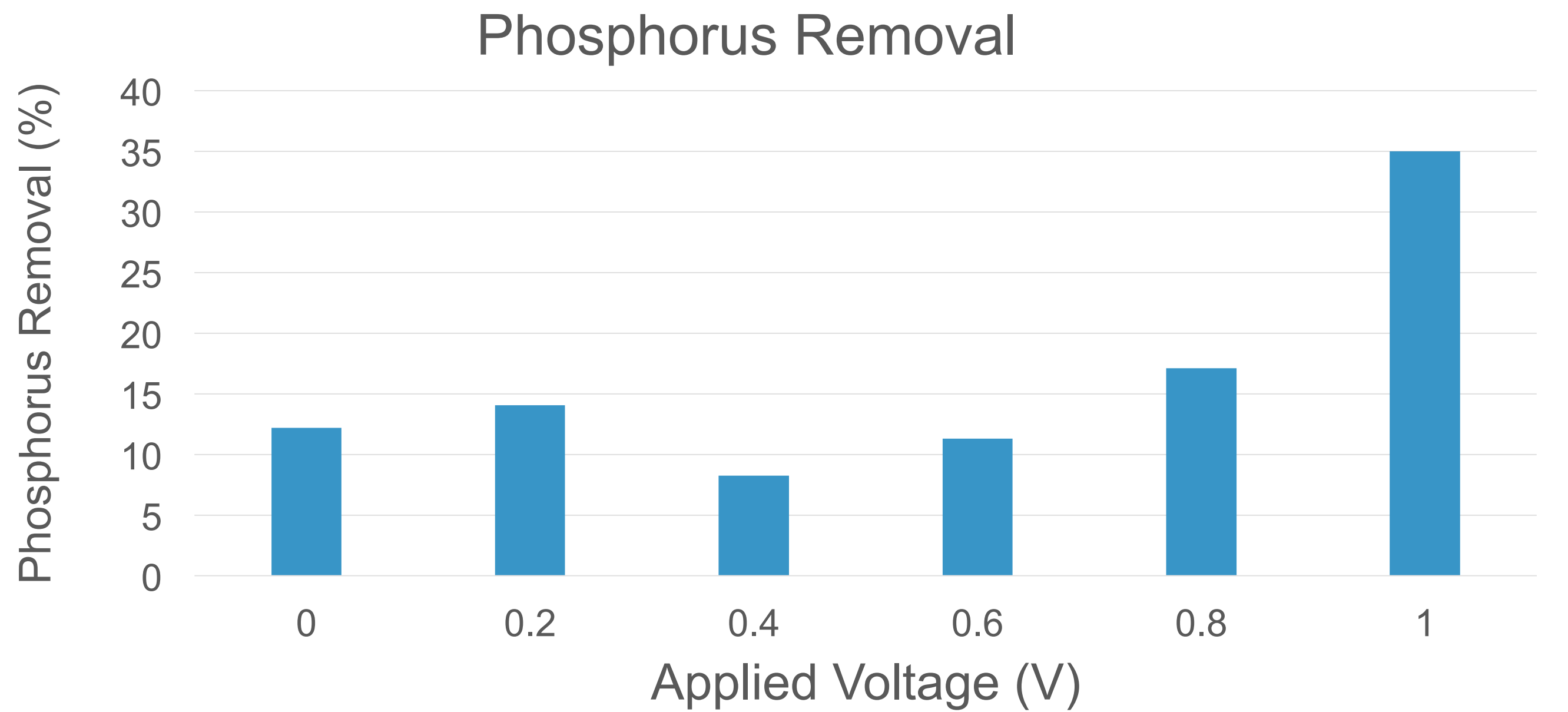
Reactor Circuit Set-up

Six electrodes (A & B) were initially constructed for each of the six differing reactors. The electrodes consisted of: titanium wire (30GA), coated wire, type 430 stainless steel 10x10 mesh (.025in, cut into 15cm x 4cm), and silver conductive epoxy adhesive. Each electrode then has approximately 240mm². Six reactors were then constructed using simple plastic bottles with a cap containing three holes for the anode wire, cathode wire, and for access to the liquid manure for measurement. The electrodes were placed inside each reactor with the appropriate wires protruding from the cap. The exposed wires were the logical choice in connecting the circuit that was desired. The above left figure is a representation of the reactor set-up. The above right picture is the exact reactor circuit set-up including each of the five reactors, the DC power supply, and the necessary resistors.

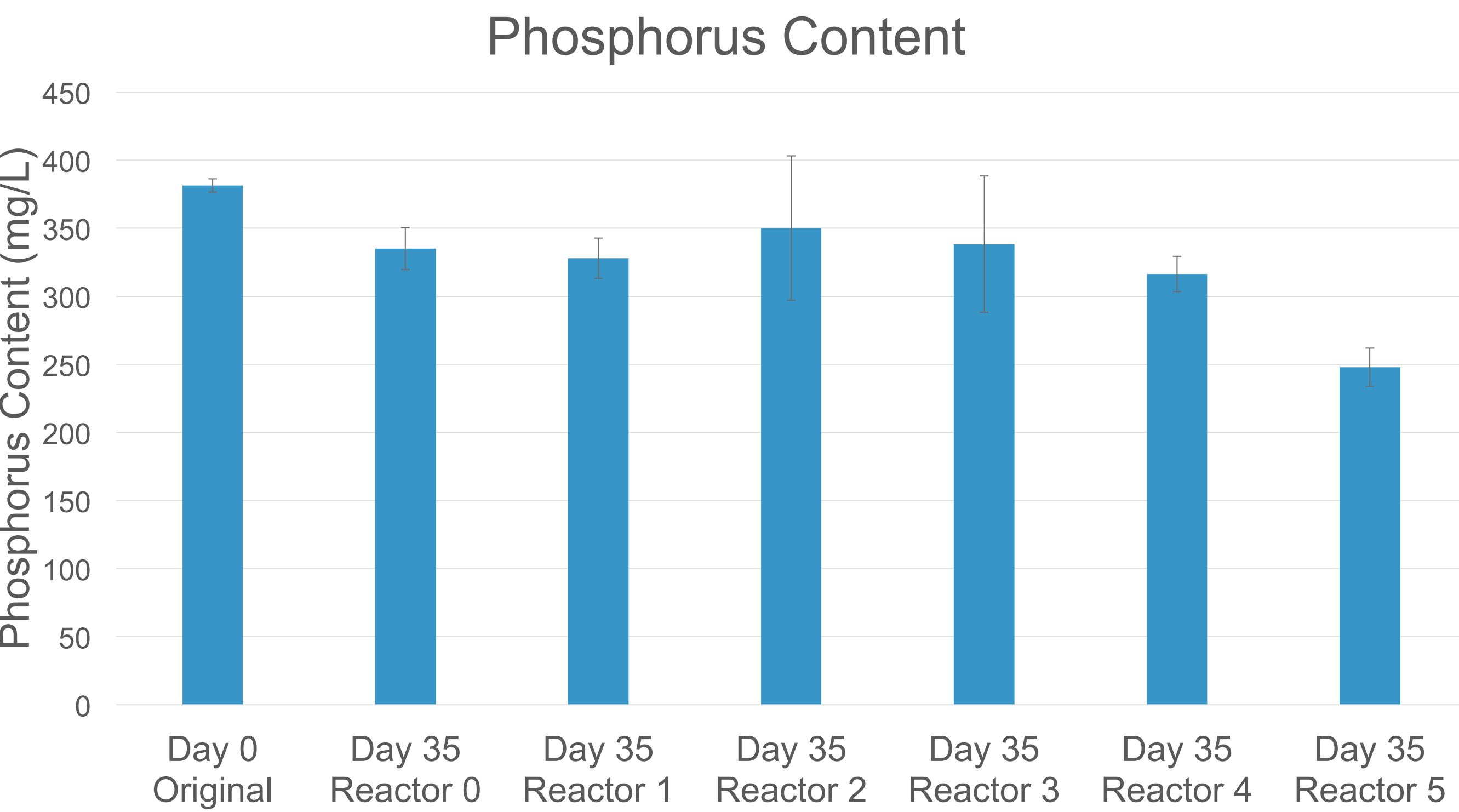
Results

The 1.0V reactor should precipitate the largest amount of phosphorus out of solution, compared to the control reactor which will have the least precipitated phosphorus. The initial claim of a correlation between higher voltage and precipitate formed can be best represented by the 1.00 V reactor due to the top concluding at 80.4 mgPO₃-P/L, the middle at 170.4 mgPO₃-P/L, and the top at 508 mgPO₃-P/L. Without including the control reactor, each reactor ends with a higher concentration of phosphorus in the bottom and a lower concentration in the top, compared to the middle of each reactor. In theory, an increase in the applied voltage will produce an increase in phosphate precipitates. The suggestion of consistently increased amounts of precipitated phosphates correlated to a consistent applied voltage increase cannot be experimentally confirmed here due to the 0.4 V and 0.6 V reactors. The assumption that a higher voltage will precipitate more phosphorus out of solution, however, can be made because of the general trend of phosphorus removal and especially the 1.0 V reactor. The 1.0 V reactor precipitates almost double the amount of the 0.8 V reactor and more than double for all of the others. This could suggest 1.0 V to be the ideal voltage for precipitation, or even that an applied voltage higher than 1.0 V could be used.

Results



Above: Phosphorus removal given as a percentage of total phosphorus in solution at the end of experimental operation.
Below: Date with phosphorus concentration for each reactor.



Conclusions

The removal of phosphorus from wastewater can differ greatly and scientists continue to examine these ways in hopes of an energy and cost efficient process with high results. Experimental data from earlier shows that 8-35% of the total phosphorus concentration can be removed from solution with an application of 0-1.0 V to an electrode in an MEC, with 35% coming from the highest voltage reactor. Although this study contained a set of reactors of 500mL size, it would take much larger reactors to have an effect on the eutrophication of aquatic autotrophs that is desired in the long run. Even scaled up, this process will need configurations leading to increased phosphorus removal rates; 35% is not high enough for large scale application. Experimental data, however, does show that this financially plausible small scale set-up using 1.0 V of applied voltage could precipitate a noticeable amount of phosphorus out of solution.